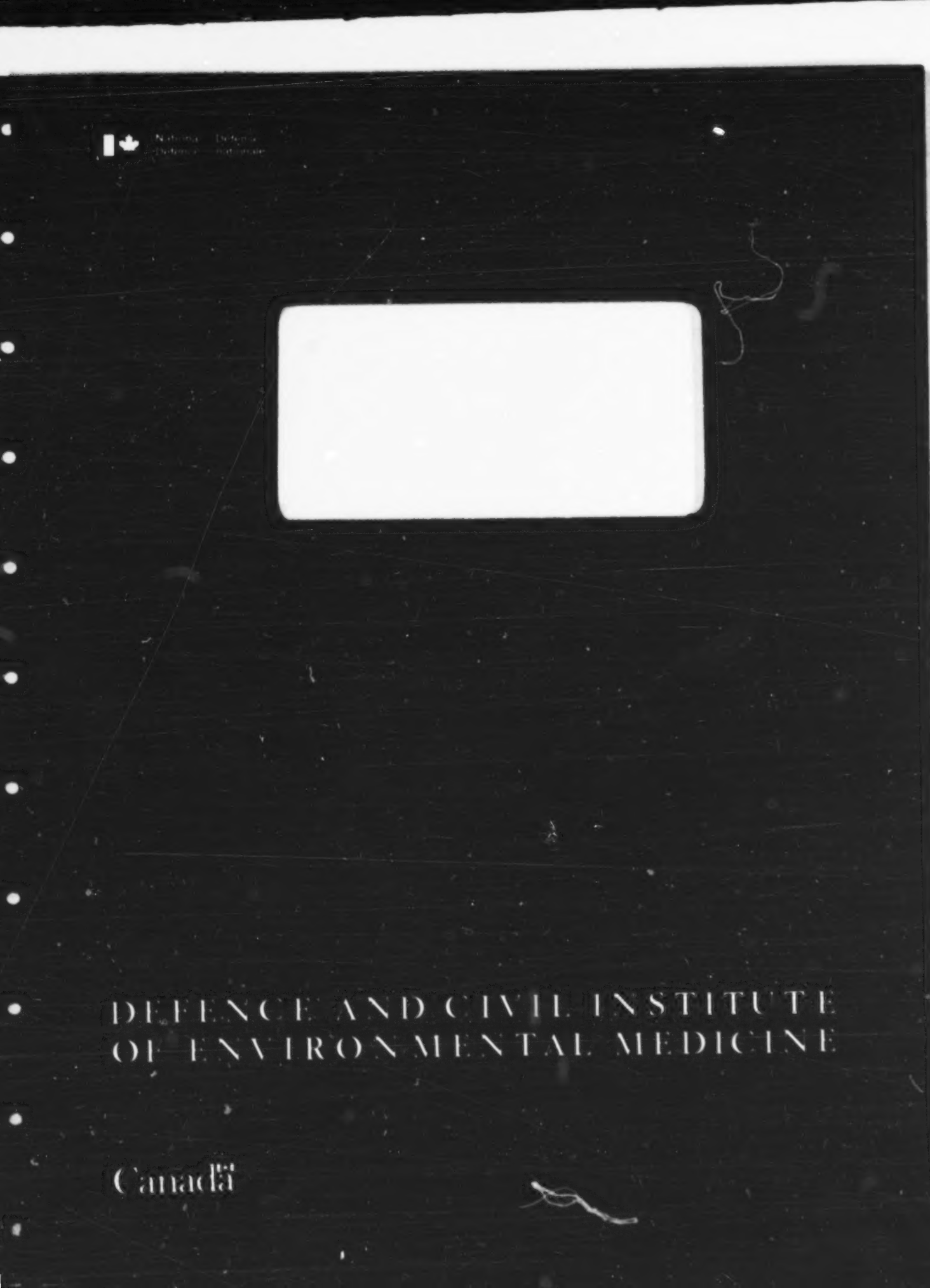
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A HUMAN ENGINEERING ANALYSIS OF DDH280 BRIDGE ACTIVITIES: TACTICAL EXERCISES.

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ABSTRACT

Through a human engineering evaluation of movement, communication and equipment usage patterns during tactical exercises, limitations in the design of the DDH280 bridge are identified. The conclusions drawn from each of these analyses are compared to those from a previous analysis of bridge activities during harbour entrances and exits. Several of the problems identified were found to be common to both types of activities. In addition, the study of tactical exercises highlighted the requirement for better internal ship communications and workstation design. Recommendations for improvements to the bridge are included.

INTRODUCTION

In December 1982, the Directorate of Marine and Electrical Engineering (DMEE) requested the Defence and Civil Institute of Environmental Medicine (DCIEM) to undertake a human engineering analysis of the DDH280 bridge. This analysis would establish requirements for the redesign of the bridge within the context of the Tribal Class Update and Maintenance Project (TRUMP). Specifically, DCIEM was asked to identify any deficiencies in the existing bridge design, investigate design alternatives, and establish a list of design options (1).

The research effort was organized under a three phase workplan. The work carried out to the end of 1983 was summarized in a previous DCIEM report (2). That report outlined the analysis procedure used to identify existing deficiencies in the DDH280 bridge design by analyzing movement patterns, communication patterns, and equipment usage patterns for the key bridge personnel during harbour entrances and exits. The problems and design requirements identified in the study were reported and used as a basis for development of improved bridge design (3). In addition, a detailed review of factors related to bridge visibility (ie vision available from the bridge) was carried out (4). The data from the harbour entrances and exits were used as the basis for the design development due to the high number of personnel on the bridge and the high degree of movement required by the personnel in order to complete their tasks. Nevertheless, it was recognized that the bridge activities related to tactical exercises should be reviewed. Therefore, a similar approach was taken in studying bridge activity during tactical exercises. This report records the conclusions drawn from observation and recording of an anti-aircraft gun exercise (AIREX), two anti-surface gun exercises (GUNEX), and an Officer of the Watch manoeuvres exercise (MANEX).

The objectives of the report are to:

1. document the activities occurring on a DDH280 bridge during tactical exercises;

2. compare these data to those obtained previously during harbour exits and entrances (2); and

3. note possible implications for bridge design.

METHODS

All information was gathered aboard HMCS HURON in May 1984 while the ship was on exercise in the North Atlantic. The bridge complement during the exercises varied from 11 to 14 personnel, depending on the exercise engaged in. Previous experience, as well as discussions with several bridge personnel, determined that the activities of the following personnel would be recorded:

Commanding Officer (CO);
Officer of the Watch (OOW);
Second Officer of the Watch (2OOW);
Squadron Commander (Sq CO);
Weapons Officer (WPN O); and
Signalman (Comms).

An activity sampling method (5) was used to quantify the movement patterns, communication patterns, and equipment usage patterns of those bridge personnel. This involved recording the position of each of the above listed personnel, the identity of the personnel that they talked to, and any item of equipment that they used. In order to record the data, the bridge was divided into numbered areas, each member of the bridge complement was assigned a number, and each item of equipment was assigned a number. Appendix A contains a listing of the numbers and positions used. It should be noted that there is no relationship between the three legends used, since each was used independently.

Three observers each monitored and recorded data for two bridge personnel, sampling every 15 seconds. This resulted in a 30 second sampling interval for each subject. This interval was considered to be short enough to capture the predominant movement patterns of the personnel studied in the tactical exercises. Care should be taken in interpreting the results, however, since the movements of very active bridge personnel are underestimated using this sampling interval.

A total of 120 minutes of records were taken during the tactical exercises (AIREX, GUNEX, MANEX). All records were made during daylight conditions with sea states below 3. Although members of the bridge complement were aware that records were being taken, they did not know when their specific activities were being recorded. All recordings were made on paper and later analyzed on a HEWLETT PACKARD 9845B computer. Previously developed analysis software was used to summarize and tabulate the results. The following measures were quantified:

For the movement analysis:

1. time spent by each subject at various positions,
2. frequency of movements each subject made to and from those positions,
3. sequence of movements to and from those positions;

For the communication analysis:

1. frequency of subject to subject conversations,
2. sequence of subject to subject conversations;

For the equipment usage analysis:

1. frequency of use for each piece of equipment.

RESULTS

Movement Analysis

The results obtained from the movement analysis of the individual personnel are reported in the following sections. In Figures 2 - 6, the origins and destinations of movements are plotted, and the frequencies of movements are represented by the thickness of the lines. In order to simplify the figures, only movements that occurred more than twice have been plotted. A complete listing of the movement data is presented in matrix format in Appendix B. Since Figures 2 - 6 contain only movement data, it is not possible to use them to determine the time spent in each area. For this reason, the percentage of time spent in each area is presented together with the movement patterns for each person recorded.

In interpreting the figures, care should be taken in distinguishing between the percentage of time spent in an area and the frequency of movements to that area. For example, it was possible for a bridge member to move to a given area infrequently, but stay in that area a long time, thereby having a high percentage time in, but a low frequency of movement to, that area. Conversely, it was possible for a bridge member to have a high frequency of movement to, and a low percentage of time in an area by making several movements to an area, but staying in that area only for brief periods.

The following figure presents the layout of HMCS Huron (DDH281) bridge as it was at the time of the study.

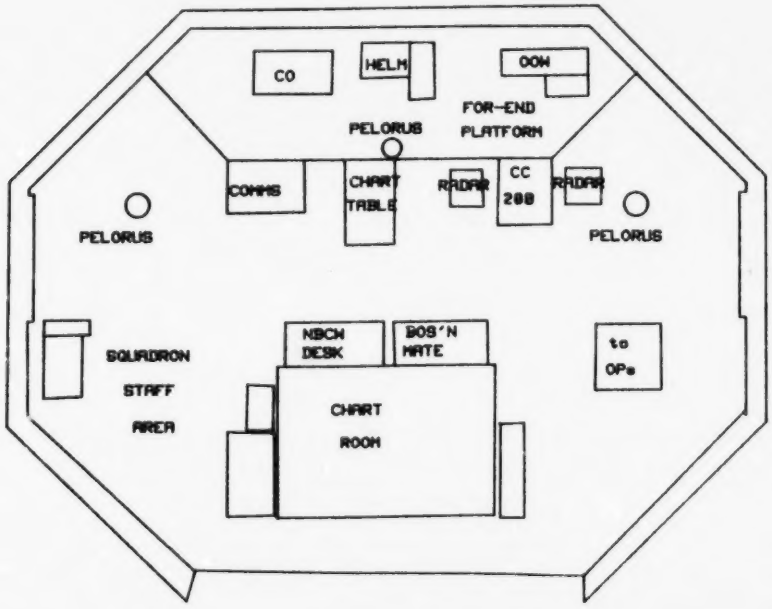

Figure 1. Layout of the Bridge of the Huron.

Movements of the CO

The CO spent his time on the bridge as follows:

% time	Area
33	bridge wings
17	aft of CO console
17	aft of helmsman console
10	radar displays
8	communications desk
7	pelorus
8	other

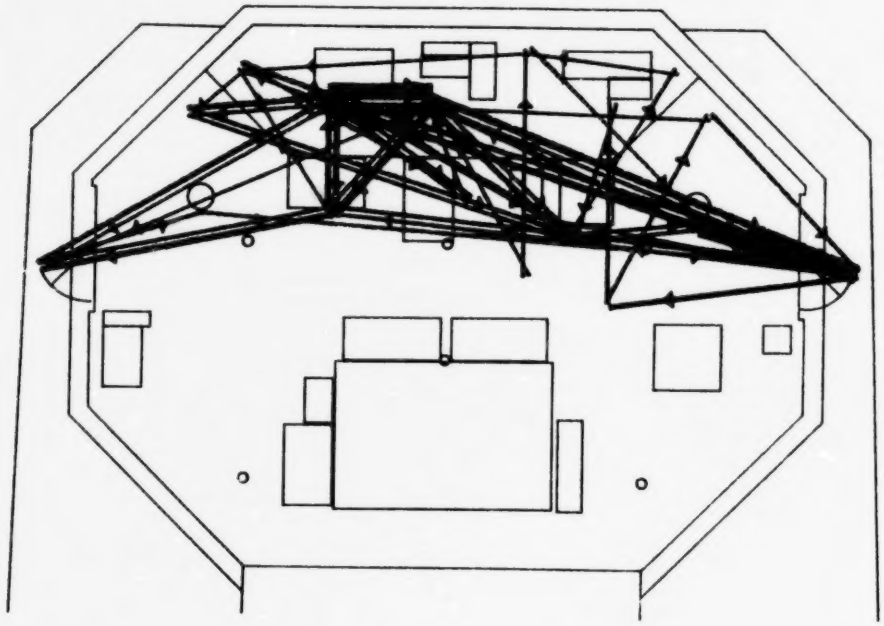

Figure 2. Movement patterns of the CO.

During the tactical exercises, the CO made a total of 94 movements, an average of 1 movement every 1 minute, 16 seconds. Figure 2 displays the CO's movements during the total exercise period. It shows that the CO's activities were centred around his console, the helmsman's console and the comms desk. Almost 30% (31/94) of his movements from this area were made to and from the bridge wings. This, coupled with the relative percentage of time spent on the bridge wings, indicates that each excursion the CO made to the bridge wing was of relatively short duration. Frequent movements were also made between the central bridge area and the platform at the for-end of the bridge. The CO seldom moved into the after third of the bridge.

The most common sequence of three movements in descending order were: from the CO's console to the helmsman's console to the comms desk; and from the for-end platform to the bridge wings and back.

Movements of the OOW

The OOW spent his time on the bridge as follows:

% time	Area
43	aft of helmsman console
25	bridge wings
9	mid bridge, off the centreline
8	CO console
7	OOW console
8	other

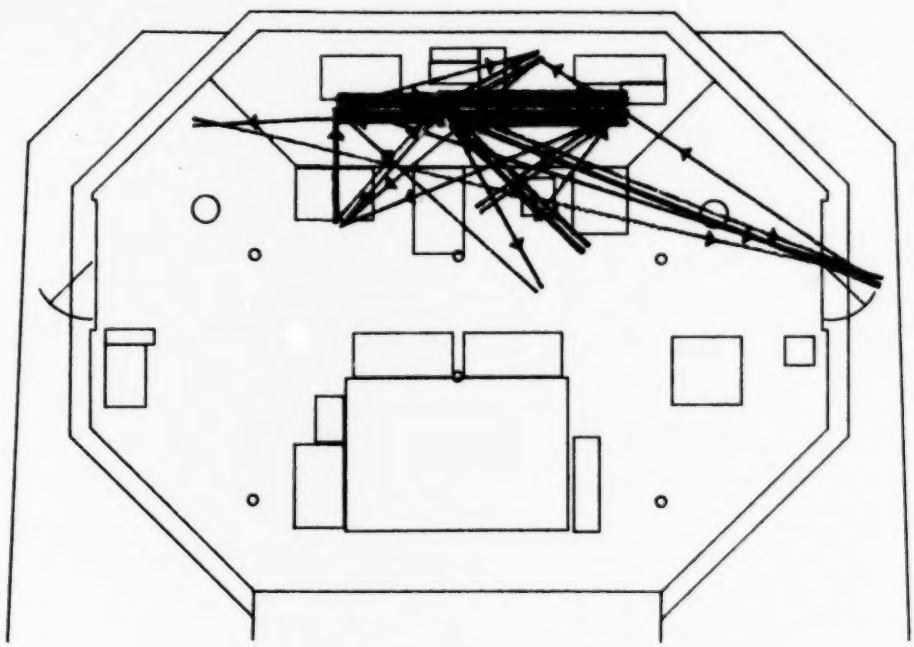

Figure 3. Movement patterns of the OOW

During the exercises, the OOW made a total of 66 movements; an average of 1 movement every 1 minute, 49 seconds. Figure 3 displays the movement patterns for the OOW and shows that his movements were almost exclusively in the central bridge area. Frequent movements were made along the for-end platform and between the various consoles in the centre of the bridge. Very few movements were made to the bridge wings. However, the percentage of time spent on the bridge wings indicates that each excursion to the bridge wing was of relatively long duration. The OOW did not move to several areas of the forward bridge and never moved to the after third of the bridge.

The movement patterns indicate that the most common sequence of three movements was on the for-end platform between the OOW console, the CO's console and the helmsman's console.

Movements of the 200W.

The 200W spent his time on the bridge as follows:

% time	Area
72	chart table
15	radar displays
3	bridge wings
10	other

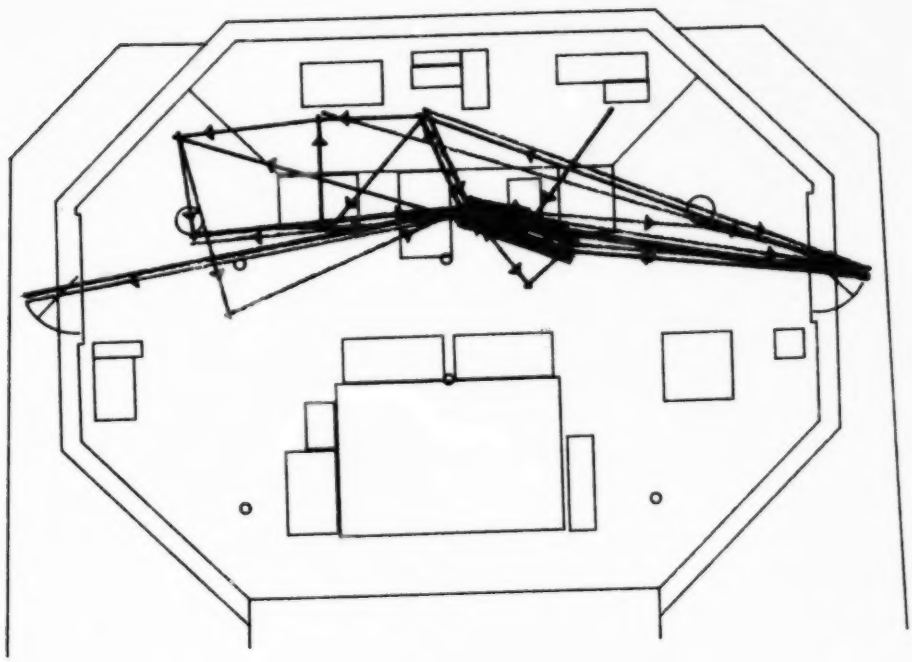

Figure 4. Movement patterns of the 200W

The 200W made a total of 51 movements during the exercises; an average of 1 movement every 2 minutes, 21 seconds. Figure 4 displays the movement patterns for the 200W and shows that his movements were concentrated around the radar displays. His most frequent movements were made from the radar displays to the chart table, where he spent relatively long periods of time, and from the for-end platform to the bridge wings.

His most frequent sequence of three movements was from either of the two radar displays to the chart table and back to the radar displays.

Movements of the Squadron CO

The Squadron CO spent his time on the bridge as follows:

% time	Area
36	squadron staff area
23	front windows
13	pelorus area
13	bridge wings
15	other

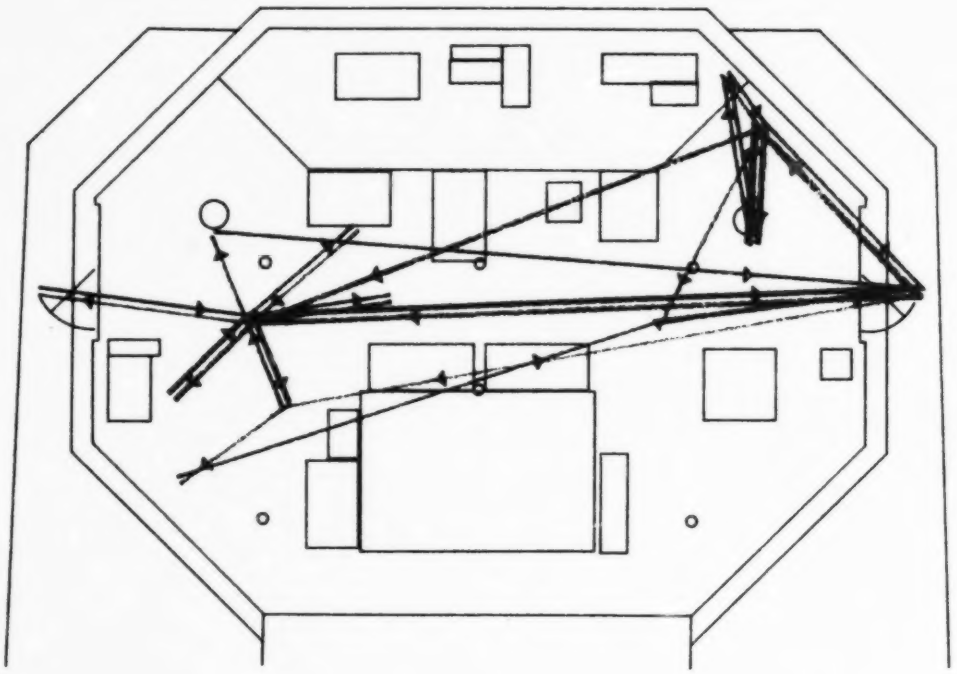

Figure 5. Movement patterns of the Squadron CO

During the exercises, the Squadron CO made a total of 41 movements; an average of 1 movement every 2 minutes, 55 seconds. In Figure 5, it is evident that the predominant movements of the Squadron CO were laterally across the bridge from the squadron area in the port after section to both of the bridge wings. Some activity was also observed on the starboard side of the bridge near the pelorus. The Squadron CO was generally quite mobile, but remained in the areas of the bridge that were not crowded by other people.

His most common sequences of three movements were between various positions in the squadron area, and from the squadron area to both the bridge wings and forward quarter windows.

Movements of the Weapons Officer

The weapons officer spent his time on the bridge as follows:

% time	Area
40	aft of helmsman's console
27	comms desk
7	forward windows
6	bridge wing
6	radar displays
14	other

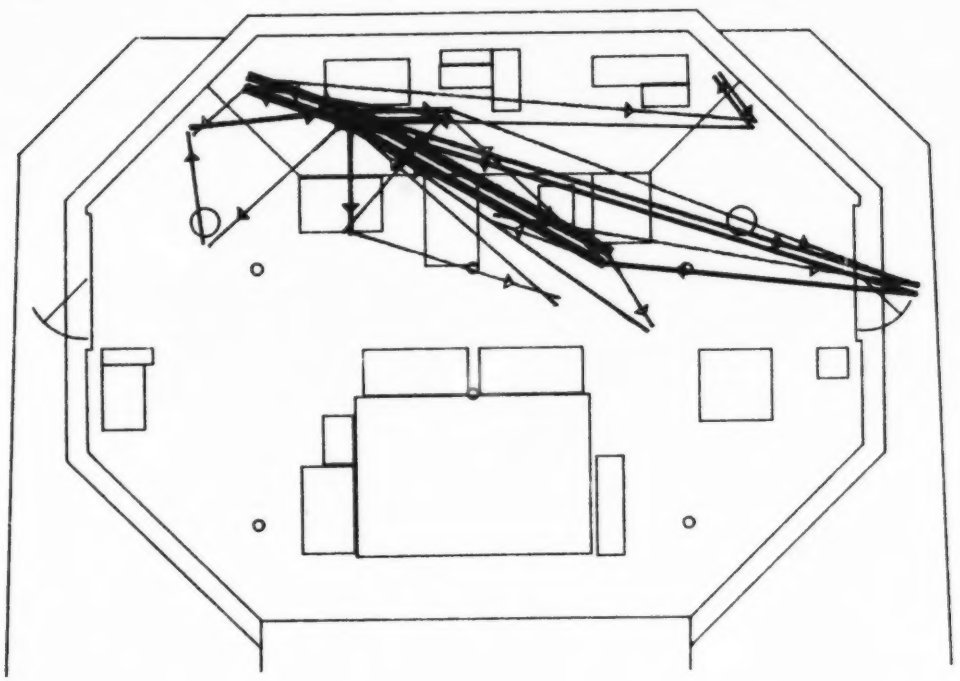

Figure 6. Movement patterns of the Weapons Officer.

During the tactical exercises, the Weapons Officer made a total of 46 movements; an average of 1 movement every 2 minutes, 36 seconds. Figure 6 indicates that the Weapons Officer was generally quite active with his movements concentrated around the CO's console, the forward windows and radar displays. Several lateral movements were made across the bridge to the bridge wings. The Weapons Officer never went to the after third of the bridge.

His most common sequence of three movements were from the CO's console to the radar displays to the front windows.

Movements of the Signalman

During the tactical exercises recorded, the Signalman remained closed up at the communications desk. Therefore, he made no movements.

Findings from the Movement Analysis

The movement patterns of bridge personnel observed in the tactical situations revealed three major findings. First, the amount of movement on the bridge was not high. Most personnel conducted their activities from a limited number of positions, thereby minimizing their movements about the bridge. Of the personnel recorded, the CO was the most active. The Squadron CO, 2OOW and Weapons Officer each made almost 50% less movements than the CO.

Second, the majority of all personnel activity was concentrated aft of the for-end consoles on the bridge and forward of the chart room bulkhead. More than half of the total activity of the 5 personnel observed was in that area. Most movement was made immediately forward or aft of the communications desk, the chart table and the radar displays. Relatively few movements were made to the forward bridge windows or the after third of the bridge. Thus, the heaviest concentration of movement was in that area of the bridge most crowded in terms of consoles, stanchions and other obstacles. Those obstacles hindered general movement, forcing personnel to take circuitous routes from one position to another. Such deviations are not plotted in the figures but show up as links crossing the consoles. The movement patterns also forced personnel frequently to step on or off the platform which runs across the for end of the bridge.

Third, relatively few movements were made to the area of the interior bridge pelori. This was due to the fact that navigation was not an important task in the tactical exercises. However, since the NavO and the FixO were often on the bridge during the tactical exercises, they tended to remain around the central bridge area obstructing the movement of other personnel who were forced to move around them.

Communication Analysis

Figure 7 presents a summary of the voice communications made within the bridge over the 120 minute duration of the recorded exercises. The number of recorded communications to and from personnel is indicated by both the width of the line and the number beside the line. Only communications that occurred more than five times in the two hour period are included in the figure. A complete listing of the all communications can be found in Appendix C. It should be noted that several communications that one would expect to occur are not shown in the figure. This is due to the fact that not all of the personnel shown in the figure had their actions recorded. The helmsman is an example of this. He responded to every helm and engine order from the OOW, but these responses do not show up in the communications analysis.

The analysis of the sequences of information transfer revealed that the vast majority of communications were of short duration. From observations, most communications on the bridge were less than 15 seconds long. Thus, the data presented in Appendix C do not reflect dialogues, but what was predominantly one way communications.

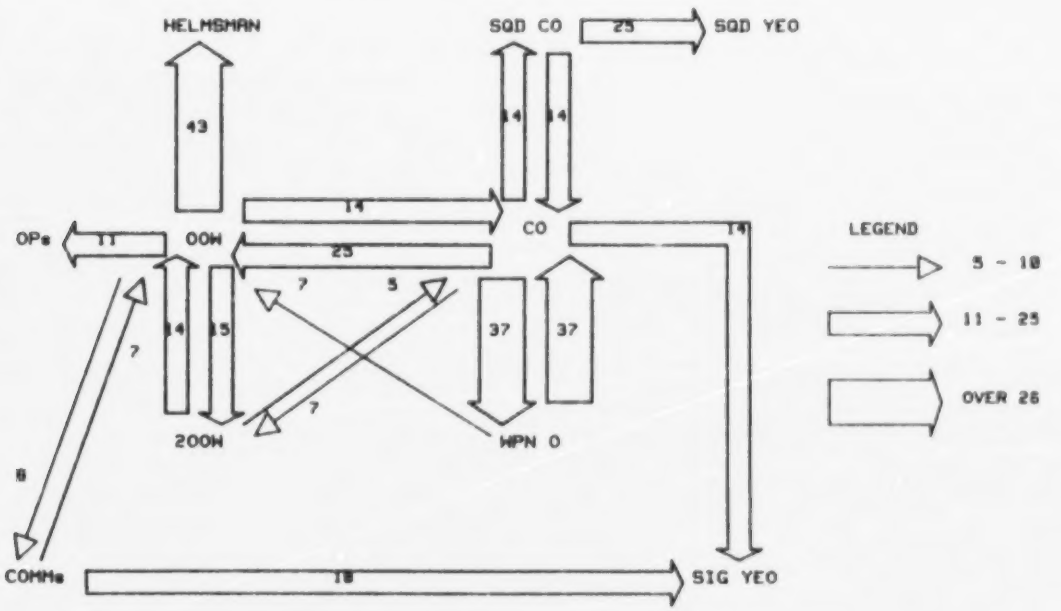

Figure 7. Voice communication patterns for all personnel.

Figure 7 indicates that the bridge personnel were divided into several functional groups based on their communication patterns. These groups were responsible for specific bridge system functions. Group members communicated almost exclusively with each other and seldom spoke to personnel in other groups. The CO and the OOW were central figures of several groups. The OOW, the CO, and the Helmsman formed a communications group handling information for the conning of the ship. The CO, the OOW, the 200W, and the Ops room handled information for the implementation of the tactical activities of the bridge. The CO and the Weapons Officer worked together to coordinate the use of the ship's weapons. The CO, Comms, and the Signalman's

Yeoman comprised the external communication team, while the Squadron CO and his Yeoman worked to coordinate the tactical activities of the squadron.

The importance of face to face communication between the OOW, the CO and other bridge personnel is also demonstrated in Figure 7. The OOW and the CO were the sources and recipients of the greatest number of information exchanges on the bridge. During the two hour observation period, they initiated 258 orders and received 124 responses, an average rate of almost 100 messages per man hour.

The OOW made frequent communications with several personnel. He spoke primarily to the Helmsman, the CO, the 2OOW, and the Signalman. The OOW received information mainly from the CO, the 2OOW, the Ops room, and the Signalman.

The CO also had frequent communications with a number of personnel. He primarily sent information to the Weapons Officer, the OOW, the Squadron CO, and the Signalman's Yeoman. This indicates that decisions made by the CO were passed down the chain of command through several different channels. The CO was also the final recipient of information. This is to be expected since he is the final link in the upward flow of information through the chain of command. His primary sources of information were the Weapons Officer, the Squadron CO, the OOW, the 2OOW and the Signalman's Yeoman.

The most frequent information interchange on the bridge occurred between the OOW and the Helmsman during the relaying of conning orders. This heavy reliance on voice communication to successfully con the ship required that the orders from the OOW be audible at the helmsman console at all times. Often, this was not the case, especially when the OOW was on the bridge wings and several people were located close to the helm.

The Squadron CO's only communication with other bridge personnel was through the CO. The high mobility of both the CO and Squadron CO often inhibited close face to face communication between them. It was observed that this usually forced one or both of the officers to move if they wanted to communicate to each other.

Findings from the communications analysis

1. The majority of communications on the bridge were less than 15 seconds long, and one way.

2. Extensive use was made of voice communications from both the OOW and CO to several key bridge personnel.

3. Unobstructed face to face communication between team members was essential to the implementation of a number of bridge tasks.

4. There was no direct communications link between the OOW and the Helmsman. This forced the OOW to shout his orders to the Helmsman, particularly from the bridge wing, thereby creating opportunities for confusion and adding to the general noise levels on the bridge.

5. The present method of Ops room communications to the bridge in terms of access and location created unnecessary delays in the transfer of information.

Equipment Usage Analysis.

Table 1 contains a listing of the various bridge personnel and the number of 30 second sampling periods during which they accessed different items of equipment over the 120 minutes of the recorded exercises.

Table 1. Equipment usage by the various bridge personnel.

User	Equipment Number (See Legend)														
	3	4	6	9	11	16	17	18	20	21	23	26	27	28	Total
OOW		37	5		7				7	2	11		1	2	72
2OOW		4	12		73					14	15				118
CO		2	9	16	1				16	8	16		1		69
Comms	5	1		1		4	15	1			3	15			45
SqCO				12											12
WPN O		1		10	4			1	27	8	32	1	2	2	88
Total	5	45	26	39	85	4	15	2	50	32	77	16	4	4	

Equipment legend for Table 1.

3 - I/C control
4 - Pelorus
6 - Sperry radar
9 - windows
11 - chart table
16 - Omega
17 - radio control
18 - VHF radio
20 - binoculars
21 - CC 280
23 - execuphone
26 - writing surface
27 - voicepipe
28 - other

The most used items of equipment (excluding the bridge windows), in descending order of use, along with the users of that equipment in descending order of use were:

1. Chart table - used by the 2OOW and the OOW
2. Execuphones - used by the WPN O, CO, 2OOW and the OOW
3. Binoculars - used by the CO and the Squadron CO
4. Pelori - used by the OOW
5. CC280 - used by the 2OOW, CO and the OOW
6. Sperry radar - used by the 2OOW, CO and the OOW
7. Writing surface - used by the Signalman and his Yeoman
8. Radio controls - used by the Signalman and his Yeoman.

The bridge windows were not included in the above list since it was very difficult to determine when and if the bridge personnel were using them. Often a person would be looking across the bridge and it was not possible to determine if they were looking at something within the bridge or were looking through the windows to the horizon. Also, since the need for good all round visibility from the bridge was the topic of a previous report (4), it was felt that it was not necessary to further substantiate that finding here.

Table 1 indicates that all personnel tended to make primary use of one

or two items of equipment (disregarding the use of the windows and binoculars), although they did utilize other items of equipment. During one exercise, (MANEX), the OOW used the pelorus for confirming contacts that were relayed from the Ops room. During all other exercises, his equipment usage was diffuse. The CO used the binoculars, the windows, and the execuphone to coordinate the ship's activities. The 2OOW used the chart table to plot the tactical information that was required. The Signalman employed radio controls and a writing surface to conduct his activities. The Weapons Officer's primary equipment were the execuphone and the binoculars.

It was noted that the current bridge layout does not permit personnel ready access to all the equipment that they most frequently use. For example, the OOW must be able to use the CC280 and the Ops room communications. With the current layout, it is very difficult for him to use those two items of equipment simultaneously because of the distance between them.

A final observation of the equipment usage analysis concerns the execuphones. Those phones were used often by several of the bridge personnel. The execuphones most used were those at the communications desk. Often the user would have to travel across the bridge to the comms desk in order to conduct the required communication. This created unnecessary delays in the transfer of information. As previously stated, it is felt that having several execuphones distributed throughout the bridge, or some form of "man-on-the-move" communications would improve the information handling considerably.

Findings from the equipment usage analysis.

1. Each member of the bridge complement used primarily one or two items of equipment.

2. Equipment was often located where it could not be easily accessed by the user.

3. There were unnecessary delays in the transfer of information because of the low number and location of the execuphones and lack of "man-on-the-move" communications on the bridge.

DISCUSSION

A comparison of the findings from the current analysis with those from the harbour exits and entrances (2) reveals that the majority of findings, and their implications for bridge design, were similar.

The analysis supports the conclusion of the previous study (2), that the platform at the forward end of the bridge is a hazard and should be removed. This became especially apparent during the tactical exercises when the OOW and the CO were moving continually between the radar displays, the chart table and the forward bridge area. On several occasions, especially during night operations, the platform created an obstacle to smooth movement in the forward bridge area. The effect of removing the platform would be twofold. First, there would not be the obstruction and possible trip hazard as personnel moved to the forward area of the bridge. Second, visibility from the forward end of the bridge would be improved since the windows would be much closer to being centred at eye level.

The heavy usage of the radar displays and the communications link to the Ops room indicates that those items should be co-located and clear pathways are required in the central bridge area around the various consoles in order to access them. Presently, congestion makes work around the consoles quite difficult. This conclusion is similar to that noted in the study of harbour entrances and exits (2).

The movement analysis also indicated the importance of direct access to the bridge wings from the central bridge area. However, in contrast with the movement analysis for harbour entrances and exits, there was no case of direct wing to wing movement. The need for clear pathways between the central bridge area and the interior pelori was not established due to the relatively low usage made of them during the tactical exercises.

Table 2 presents a comparison of the most frequent sequences of three movements (A to B to C) for the OOW and the CO, as recorded during harbour entrance and exits and the tactical exercises. It illustrates quite similar patterns. They also illustrate the more concentrated movement associated with tactics.

Table 2. A Comparison of Movement Sequences.

	Tactics	Harbour Entrances and Exits
OOW	OOW console - CO console - Helm	Helm - CO console - Helm Wing - Wing
CO	CO console - Helm - Comms CO console - front window - Helm	Helm - CO console - Helm Platform - Wing - Platform

In some respects, the results of the movement analysis differ from those for harbour entrances and exits (2). The pattern of movements of the bridge personnel was much more concentrated in the central bridge area. This is to be expected because there is much less need for pelorus

sightings, or for viewing the sea room immediately around the ship during tactics. In contrast, the rate of the movements of the personnel was much higher during the tactical exercises. Average rate of movement per hour for the two types of exercises are presented in Table 3.

Table 3. A Comparison of Average Movement Rates.

	Tactics	Entrances and Exits
OOW	47	26
CO	33	26
2OOW	26	9

The concentration of movement in the central bridge area argues for a bridge layout in which the for-end consoles face forward, and the second row of consoles face aft, providing rapid access to both sets of consoles. Such a layout has been examined using harbour entrance and exit data (3). However, such a layout has associated with it the concern that reference to an aft facing radar incurs the risk of port:starboard errors, and that an after facing chart table incurs problems of lighting control at night.

The analysis of communications patterns indicates the need for improvements to the present communications links made in two major areas. First, as found during harbour entrances and exits (2), the practice of the OOW shouting the conning orders to the helm is less than adequate, particularly when the OOW is on the bridge wings. An improvement to this would be to establish a direct two-way communication link between those personnel. The second improvement involves the availability of terminals required to conduct internal and external communications. As noted in the equipment usage analysis, many bridge personnel were forced to go to the comms desk to conduct their communications, often at the expense of unnecessary time and movement.

The communication analysis does not adequately demonstrate the importance of the communication link between the Ops room and the OOW. The results show that the OOW spoke with the Ops room only 11 times. However, it was noted that the OOW was usually not close to his console to receive incoming calls from the Ops room. This made it necessary for him to stop whatever activity he was involved in, and go to his console in order to talk with Ops. This resulted in unnecessary movements for the OOW and delays in the transfer of potentially important information.

Improvement to the current bridge communications and bridge to Ops room communication could take two forms. The first would be to provide more terminals distributed around the bridge, thereby giving key personnel access from more locations. The installation of a Shipboard Integrated Communications System (SHINCOMS) should improve the communications system capability, provided that a sufficient number of terminals are installed on the bridge. The second option would be some form of "man-on-the move" communications system whereby the key personnel are able to communicate with Ops and others from any position on the bridge. Although this second option may be more difficult technically, it would be preferable since the user would have instant communications with the Ops room regardless of his location on the bridge.

Comparison of the face to face communication patterns for the tactics with that of the harbour entrances and exits data (2), indicates a similar overall pattern, with some differences due to the circumstances. In both cases the OOW and CO communicate with one another and each communicates with other bridge personnel who perform supporting functions (OOW with 2OOW and helmsman; CO with Weapons Officer, Squadron CO, and NAVO). The average level of direct communication between the OOW and CO is very similar in either case, 19/hour for tactics and 20/hour for harbour entrances and exits. The average rate of verbal communication (from and to) the OOW and CO was close to 100 per man hour for both types of exercises.

The equipment usage analysis indicates that current practice for such exercises results in each member of the bridge complement using primarily one or two items of equipment, in addition to the windows and binoculars. The large amount of time the bridge personnel spent using binoculars indicates the heavy reliance that they place on visual information. The need for improved visibility from all parts of the bridge, identified in a previous study (4), was supported. It was unexpected that the most used item of equipment was the chart table, since the exercises did not involve a significant navigational requirement. The extensive use of the radar and CC 280 displays, and communications is to be expected, given the nature of tactical exercises. If a bridge were designed to be operated by a smaller complement, this pattern would undoubtedly change, with each member of the bridge complement using more pieces of equipment to conduct his activities.

Two concerns common to such analyses are whether they represent behaviour which is typical of system users, and whether the data can be applied to other situations. While it must be acknowledged that there are differences in practice between different ships, it is believed that, because the personnel activities were dictated by outside events, these activities observed do not contain a significant amount of personal variability. Such would not be expected to be the case in less demanding situations such as deep sea passage. It is also believed that, because the data are averaged over three different tactical exercises, they represent a generic exercise. The requirements of specific exercises are therefore reflected in the data, but do not produce imbalances. For example, the OOW used the starboard wing pelorus quite often during MANEX, but seldom during the other exercises. Thus, pelorus usage is identified as something which is necessary for tactical exercises, but which does not have as much importance as overall communications or radar use. Obviously, the CO would not be on the bridge in many tactical situation. From the current data, it appears that his absence would have relatively little effect on equipment usage, but would probably force the OOW to be more mobile.

CONCLUSIONS

The overall aim of the study was to document and analyze bridge activities during tactical exercises in terms of personnel movements, communications and equipment usage and to compare the findings to those previously reported for harbour entrances and exits.

The movement analysis demonstrated that the complexity of movements was lower during the tactical exercises than during harbour entrances and exits. Fewer personnel were required for the activites, and their movements were much more concentrated in the central bridge area, where the congestion of

consoles and equipment was much higher. Although more concentrated, the level of activity in terms of movements per hour was higher for the tactical exercises than during harbour entrances and exits. The layout must be such that movement between the equipment is facilitated and obstructions caused by the equipment is minimized. Therefore, the layout of the bridge consoles in the central bridge area is critical to the effectiveness of the bridge system.

From the communication analysis, it was determined that the face to face communication patterns between bridge personnel during tactical exercises were very similar to those during harbour entrances and exits. In the tactical exercises however, information exchange using communications sets was much more important than in harbour entrances and exits. This was specifically noted for communications between the bridge and the Ops room and from the bridge to other ships. The analysis noted that such communicators were often hampered by the lack of a communications terminal near where the key bridge personnel were working. Therefore, it is concluded that communication facilities must be available throughout the bridge.

The equipment analysis indicated the requirement for good external visibility from within the bridge. It also indicated a much higher use of radar displays and the tactical plot during tactical exercises than during harbour entrances and exits.

It is concluded that the activity data from the tactical exercises corroborate and in some cases complement the data from harbour entrances and exits. The latter data set the worst case in terms of numbers of personnel on the bridge, and the extent of personnel movements and usage of the chart table. The tactical activity data set the worst case in terms of average frequency of movements, and usage of the radar, tactical plot and communications.

It is also concluded that an effective bridge design which accomodates current bridge SOPs would provide the bridge personnel with the following criteria:

1. good visibility of the outside world,
2. ready movement from wing to wing,
3. ready movement from amidships to each wing,
4. ready access to pelori
5. ready access to internal and external communications terminals throughout the bridge,
6. a layout which permits individual operators to be closed up at the radar, tactical plot, chart table, OOW console, helmsman console and communications console without impeding the movement of other bridge personnel,
7. a layout which permits a smaller bridge complement (one or two personnel) ready access to the above equipment.

REFERENCES

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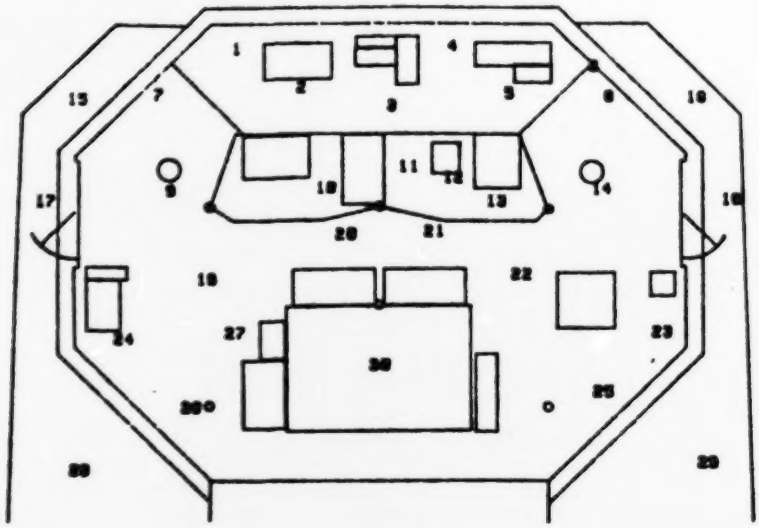
APPENDIX A

Legend Used in the Analysis

POSITION INDEX



PERSONNEL INDEX

1	OOW	12	2OOW
2	Helmsman	13	POOW
3	NAVO	14	FIXO
4	CO	15	OPs
5	XO	16	Other
6	Port lookout	17	CIO
7	Strbrd lookout	18	NAV YEO
8	Comms	19	Sig YEO
9	Quartermaster	20	Sqdrn CO
10	Boatswain	21	Sqdrn CO YEO
11	Comms Supp	22	WPN O

EQUIPMENT INDEX

0	no equipment	15	Loran
1	gyro repeater	16	Omega
2	heading angle	17	radio control
3	I/C control	18	VHF radio
4	pelorus	19	sonar
5	Spa radar	20	binoculars
6	Sperry radar	21	CC280
7	rudder angle	22	clock
8	speed indicator	23	execuphone
9	windows	24	telegraph
10	annunciator	25	whistle
11	chart table	26	writing surface
12	Decca	27	voice pipe
13	helo status	28	other
14	helo TV		

Appendix B

Complete Listing of Movement Patterns for Bridge Personnel

Movements of the CO

Origin	Destination																	
	1	2	3	4	5	7	8	9	10	11	12	13	14	17	18	21	22	31
1		1				1				1								
2	1		8			1			2	1		3		1	2			
3		6							3			1		1	3	1		
4	1												1					
5												1						
6				1														
7		2										1						1
8		1												1				
9															1			
10	1	2	1									1		2				
11		1	1															
13			2			1			1				1		2			
14		1	2										1		3			1
17		2						1	1									
18		3	1								1	1	4				2	
21				1														
22					1		1											
31	1												1					

Movements of the OOW

Origin	Destination																	
	1	2	3	4	5	7	8	9	10	11	12	13	14	17	18	21	22	31
2			6	1	2								1		1			
3		5			8	1		1	1			2	2		1	1		
4			1					1	1									
5		1	7	1				1	1	1								
7															1			
9		1	1	1														
10		2	1															
11					1													
12					1													
13			2															
14			2								1							
18			1		1								1					
21		1																

Movements of the 2OOW

Origin	Destination																
	1	2	3	4	5	7	8	9	10	11	12	13	14	17	18	19	21
2						1									1		
3		1							1	1					1		
5											1						
7								1								1	
9										2							
10		2															
11			2					1			6		1	1	1		1
12										6		1					
13						1				7					1		
14															1		
17										1							
18			1							3		1					
19												1					
21												1					

Movements of the Squadron CO

Origin	Destination																	
	6	7	8	9	10	11	12	13	14	17	18	19	20	21	22	24	26	27
6	1								1									
8	1								2		1	2			1			
9											1							
10												1						
14	1		3															
17												1						
18			3									2						2
19				1	1					1	2		1			2		2
20												1						
22											2							
24												2						
26															1			
27												1					1	

Movements of the Weapons Officer

Origin	Destination																	
	1	2	3	4	5	7	8	9	10	11	12	13	14	17	18	21	22	31
1		4				1	1											
2	4		2					1	2			5			2			
3	1	3													1			
6							1											
7		2																
8		1			1													
9						1												
10			1													1		
11															1			
13		2	1							1								
18		2										2						
21		1																
22		1																

APPENDIX C

Communications Pattern Data

The following table contains a complete listing of the communications data gathered over the two hour recording period of the tactical exercises. The six members of the bridge complement that were recorded are listed vertically, with the personnel they spoke to listed horizontally.

Personnel Communication Links																		
Speaker	Person spoken to																	
	1	2	3	4	5	6	8	9	10	12	15	16	17	19	20	21	22	Total
OOW		43		14			8		1	14	11	13		2			3	109
2OOW	15			5			2				4	8					2	36
CO	25	1			3		3			7		44		14	14		37	149
Comms	7	1	2			2		1				1	1	19		1		35
SqCO			1	14								11		1		25		52
WPN O	7	2		37	1		2			2		53						104
Total	54	47	3	70	4	2	15	1	1	23	15	130	1	36	14	26	42	485

Personnel Index for the Communication Patterns

1 OOW
2 Helmsman
3 Nav O
4 CO
5 XO
6 Lookout
8 Comms
9 Quartermaster
10 Boatswain
12 2OOW
14 FIX O
15 Ops
16 Other
17 CIO
19 Signalman's Yeo
20 Sqdrn CO
21 Sqdrn YEO
22 Weapons O

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